

Hydrocarbons Associated With Fluid Venting Processes in Monterey Bay, California

T.D. Lorenson, K.A. Kvenvolden, F.D. Hostettler, R.J. Roser, and

J.B. Martin

D.L. Orange

And the ROV

Ventana

U. S. Geological Survey, Menlo Park, CA

University of Florida

Monterey Bay Aquarium Research Institute



Introduction

The Monterey Bay National Marine Sanctuary encompasses about 14,000 km² of marine waters along the central coast of California. The centerpiece of this sanctuary is Monterey Bay which is underlain by a network of deep submarine canyons.

We have begun a multifaceted study to describe and interpret the hydrocarbons in surface and near-surface sediment of the sanctuary in order to define the hydrocarbon background and to describe the processes responsible for the hydrocarbon occurrences. Of special interest are the presence of chemosynthetic communities nestled in areas of fluid venting.

Fluid venting in the deep ocean supports chemosynthetic 'cold seep' ecosystems and may play an important role in world-wide, deep ocean ecology and element cycling. At the base of the food chain are hydrocarbons fueling the process in a world devoid of light.

A chemosynthetic 'cold seep' ecosystem occurs at a site 1,000 m deep and is interpreted as the surface expression of a mud volcano on Smooth Ridge near Monterey Canyon. Sediment samples from within and near cold seeps on Smooth Ridge were collected by push cores, using a Remote Operated Vehicle (ROV).

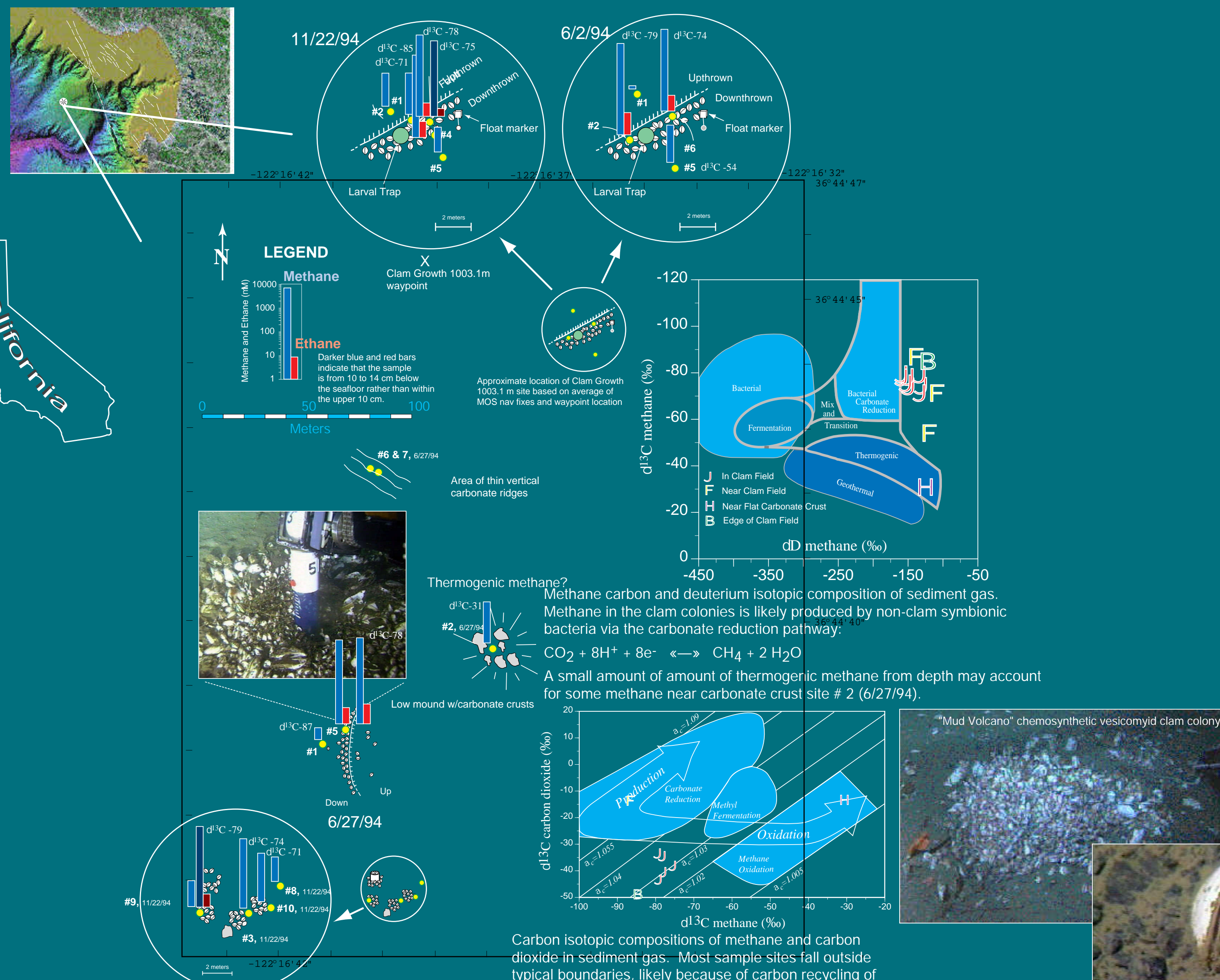
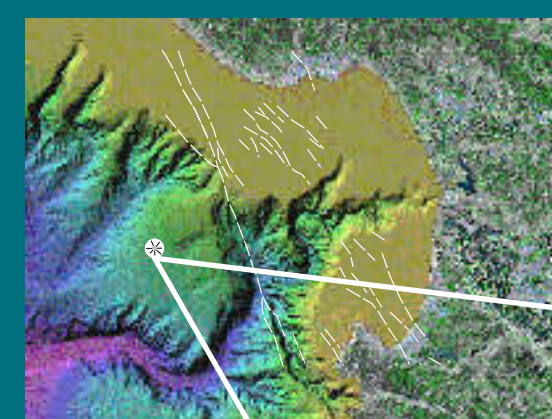
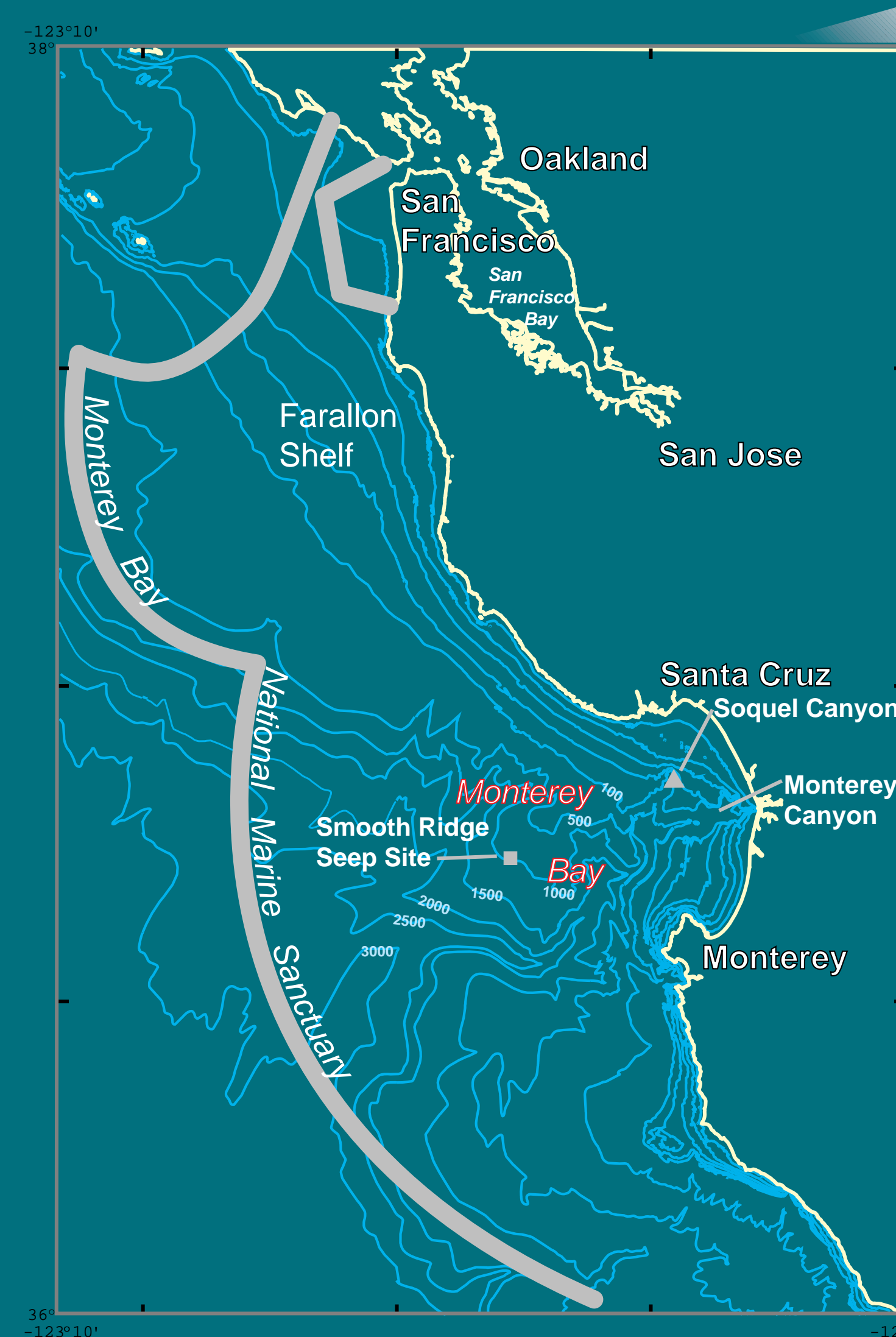


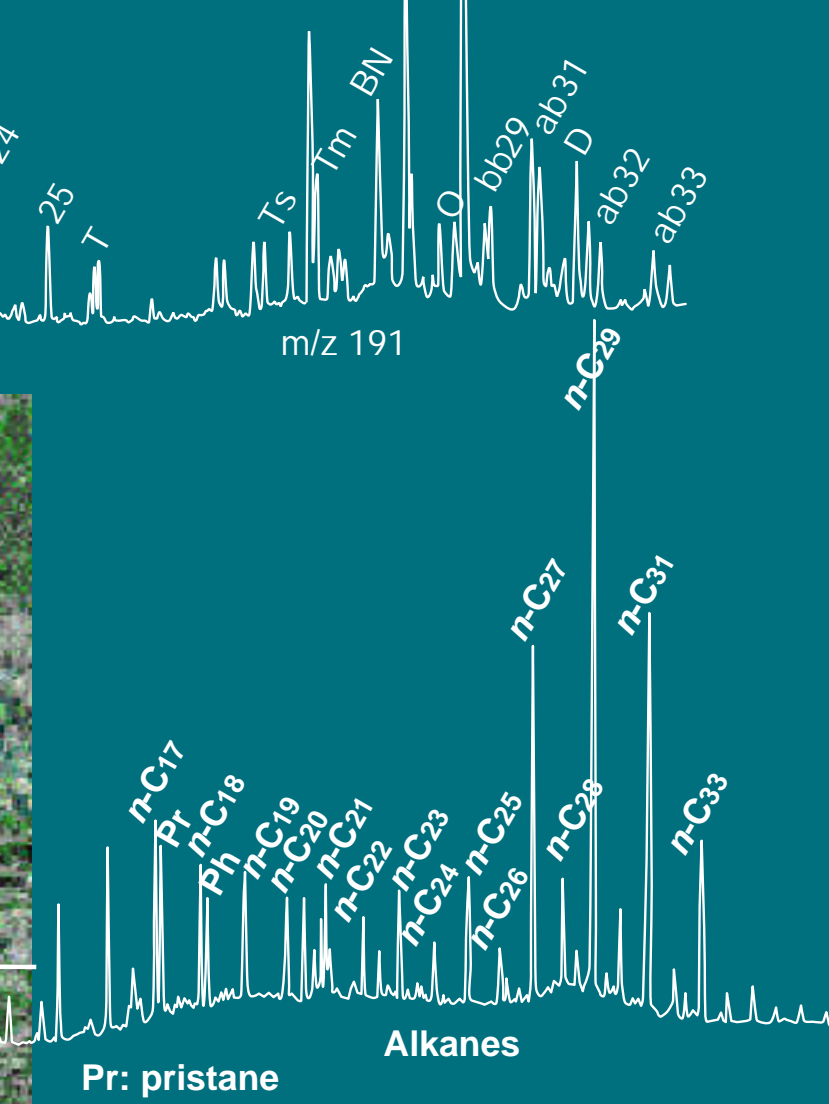
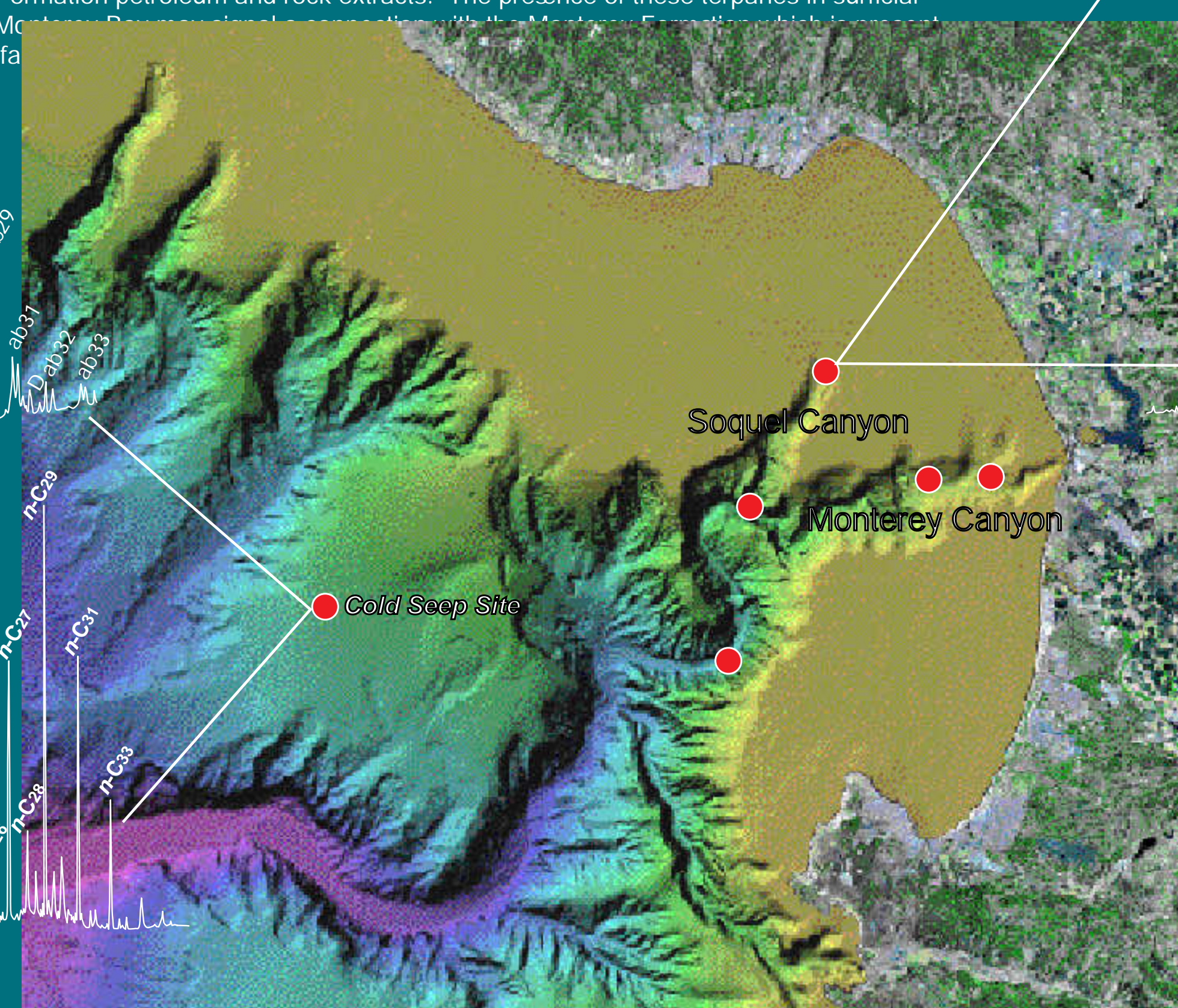
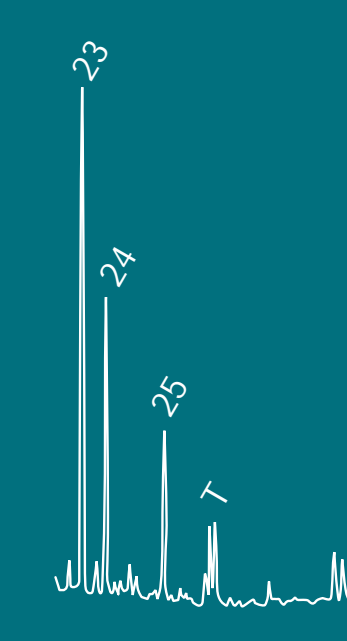
Diagram of the Smooth Ridge site. Three separate clam colonies were sampled for sediment gases and pore water chemistry on two separate occasions. Sediment near carbonate crusts and ridges was also sampled once. Methane and ethane concentrations are shown as blue and red bars, respectively, with the carbon isotopic composition of methane. The majority of hydrocarbon gas is methane. Ethane concentrations are relatively high for surficial marine sediment, occurring only within the clam colonies. Trace amounts of propane, butane, and pentane were also noted. These gases commonly appear in thermogenic fluids which may migrate up from depths of 2-3 kilometers along conduits.

Sediment Hydrocarbons

Heavy hydrocarbons are present in sediment at the seeps as well as in surficial shelf sediment obtained by conventional box coring. Aliphatic and aromatic hydrocarbons have been identified in eight sediment samples from the site of the seeps and in seven samples of surface sediment collected at or near the head of Soquel Canyon, one of the subsidiary canyons of the Monterey Canyon complex.

Aliphatic hydrocarbons at the seeps and at Soquel Canyon include acyclic and cyclic compounds. Total concentrations of acyclic hydrocarbons range from about 1 to 3 mg/g. Distributions of these hydrocarbons are similar in samples from both areas and are believed to be mainly autochthonous. The n-alkanes range from n-C₁₅ to n-C₃₆ with n-alkanes of lower molecular weight likely derived from aquatic sources (odd- and even-carbon-number molecules equally abundant) and with n-alkanes of higher molecular weight from terrigenous sources (predominance of odd-carbon-number molecules).

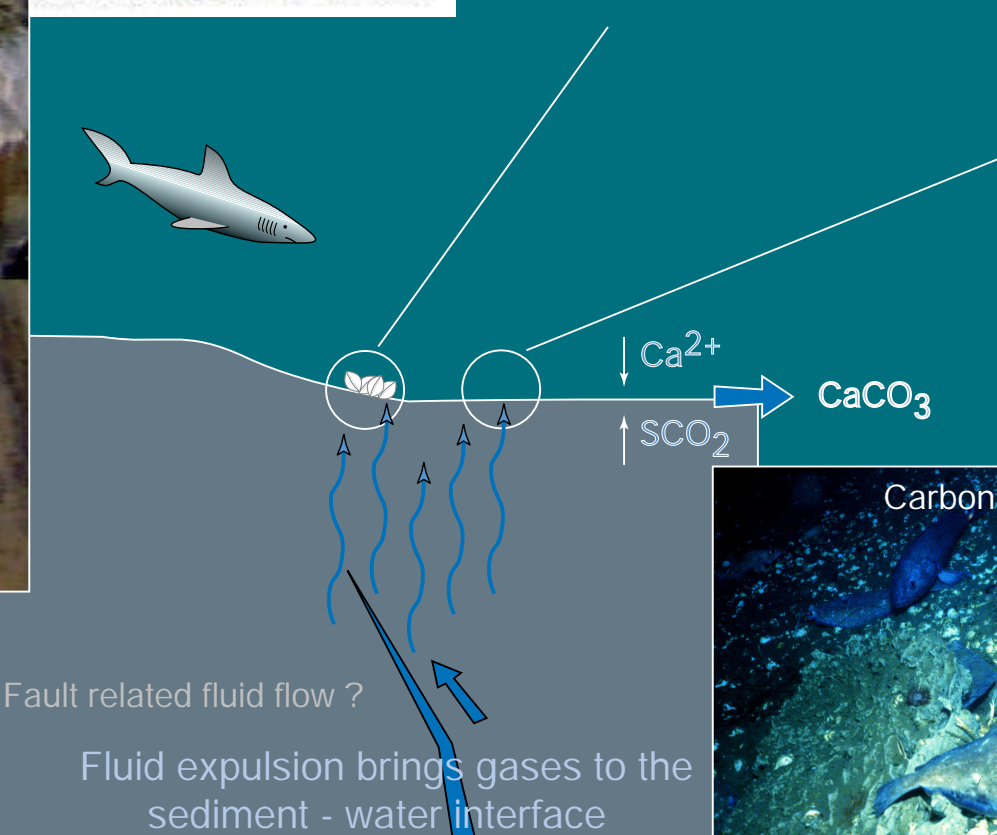
Cyclic terpanes also have similar distributions in all samples; immature biogenic molecules are present, and concentrations are low. Of particular interest, however, is the ubiquitous presence of 28,30-bisnorhopane and oleanane. These are compounds which have been commonly identified in Monterey Formation petroleum and rock extracts. The presence of these terpanes in surficial sediment of Monterey Bay is consistent with the interpretation of the Monterey Formation as a source of hydrocarbons to the subsurface.



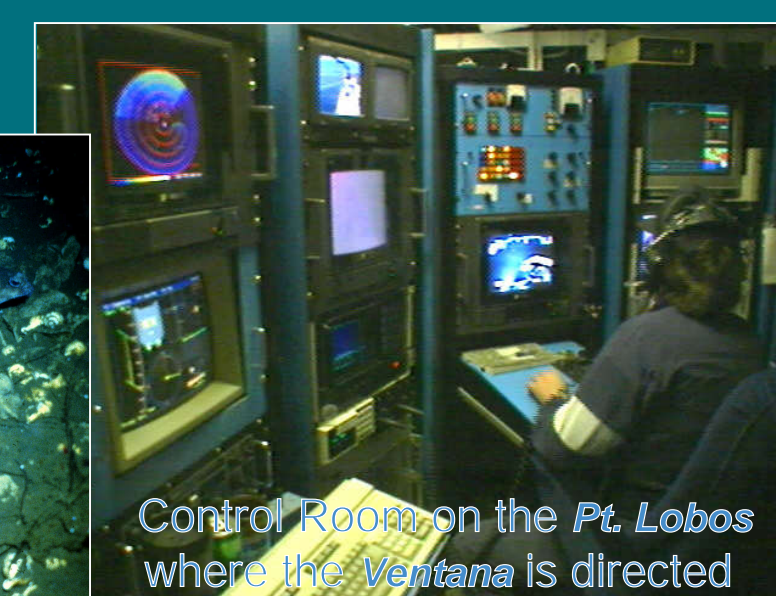
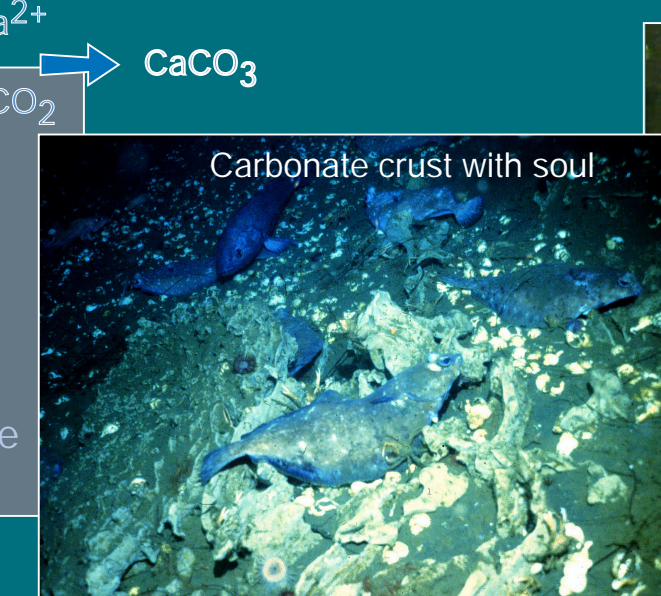
Mass chromatograms of terpanes and triterpanes (m/z=191)	
23.	C ₂₃ bicyclic terpane
24.	C ₂₄ bicyclic terpane
25.	C ₂₅ bicyclic terpane
26.	C ₂₆ bicyclic terpane
27.	C ₂₇ bicyclic terpane
28.	C ₂₈ bicyclic terpane (C ₂₇ and C ₂₈)
29.	C ₂₉ bicyclic terpane (C ₂₈ and C ₂₉)
30.	C ₃₀ bicyclic terpane (C ₂₉ and C ₃₀)
31.	C ₃₁ bicyclic terpane (C ₃₀ and C ₃₁)
32.	C ₃₂ bicyclic terpane (C ₃₁ and C ₃₂)
33.	C ₃₃ bicyclic terpane (C ₃₂ and C ₃₃)
34.	C ₃₄ bicyclic terpane (C ₃₃ and C ₃₄)
35.	C ₃₅ bicyclic terpane (C ₃₄ and C ₃₅)
36.	C ₃₆ bicyclic terpane (C ₃₅ and C ₃₆)
37.	C ₃₇ bicyclic terpane (C ₃₆ and C ₃₇)
38.	C ₃₈ bicyclic terpane (C ₃₇ and C ₃₈)
39.	C ₃₉ bicyclic terpane (C ₃₈ and C ₃₉)
40.	C ₄₀ bicyclic terpane (C ₃₉ and C ₄₀)
41.	C ₄₁ bicyclic terpane (C ₄₀ and C ₄₁)
42.	C ₄₂ bicyclic terpane (C ₄₁ and C ₄₂)
43.	C ₄₃ bicyclic terpane (C ₄₂ and C ₄₃)
44.	C ₄₄ bicyclic terpane (C ₄₃ and C ₄₄)
45.	C ₄₅ bicyclic terpane (C ₄₄ and C ₄₅)
46.	C ₄₆ bicyclic terpane (C ₄₅ and C ₄₆)
47.	C ₄₇ bicyclic terpane (C ₄₆ and C ₄₇)
48.	C ₄₈ bicyclic terpane (C ₄₇ and C ₄₈)
49.	C ₄₉ bicyclic terpane (C ₄₈ and C ₄₉)
50.	C ₅₀ bicyclic terpane (C ₄₉ and C ₅₀)
51.	C ₅₁ bicyclic terpane (C ₅₀ and C ₅₁)
52.	C ₅₂ bicyclic terpane (C ₅₁ and C ₅₂)
53.	C ₅₃ bicyclic terpane (C ₅₂ and C ₅₃)
54.	C ₅₄ bicyclic terpane (C ₅₃ and C ₅₄)
55.	C ₅₅ bicyclic terpane (C ₅₄ and C ₅₅)
56.	C ₅₆ bicyclic terpane (C ₅₅ and C ₅₆)
57.	C ₅₇ bicyclic terpane (C ₅₆ and C ₅₇)
58.	C ₅₈ bicyclic terpane (C ₅₇ and C ₅₈)
59.	C ₅₉ bicyclic terpane (C ₅₈ and C ₅₉)
60.	C ₆₀ bicyclic terpane (C ₅₉ and C ₆₀)
61.	C ₆₁ bicyclic terpane (C ₆₀ and C ₆₁)
62.	C ₆₂ bicyclic terpane (C ₆₁ and C ₆₂)
63.	C ₆₃ bicyclic terpane (C ₆₂ and C ₆₃)
64.	C ₆₄ bicyclic terpane (C ₆₃ and C ₆₄)
65.	C ₆₅ bicyclic terpane (C ₆₄ and C ₆₅)
66.	C ₆₆ bicyclic terpane (C ₆₅ and C ₆₆)
67.	C ₆₇ bicyclic terpane (C ₆₆ and C ₆₇)
68.	C ₆₈ bicyclic terpane (C ₆₇ and C ₆₈)
69.	C ₆₉ bicyclic terpane (C ₆₈ and C ₆₉)
70.	C ₇₀ bicyclic terpane (C ₆₉ and C ₇₀)
71.	C ₇₁ bicyclic terpane (C ₇₀ and C ₇₁)
72.	C ₇₂ bicyclic terpane (C ₇₁ and C ₇₂)
73.	C ₇₃ bicyclic terpane (C ₇₂ and C ₇₃)
74.	C ₇₄ bicyclic terpane (C ₇₃ and C ₇₄)
75.	C ₇₅ bicyclic terpane (C ₇₄ and C ₇₅)
76.	C ₇₆ bicyclic terpane (C ₇₅ and C ₇₆)
77.	C ₇₇ bicyclic terpane (C ₇₆ and C ₇₇)
78.	C ₇₈ bicyclic terpane (C ₇₇ and C ₇₈)
79.	C ₇₉ bicyclic terpane (C ₇₈ and C ₇₉)
80.	C ₈₀ bicyclic terpane (C ₇₉ and C ₈₀)
81.	C ₈₁ bicyclic terpane (C ₈₀ and C ₈₁)
82.	C ₈₂ bicyclic terpane (C ₈₁ and C ₈₂)
83.	C ₈₃ bicyclic terpane (C ₈₂ and C ₈₃)
84.	C ₈₄ bicyclic terpane (C ₈₃ and C ₈₄)
85.	C ₈₅ bicyclic terpane (C ₈₄ and C ₈₅)
86.	C ₈₆ bicyclic terpane (C ₈₅ and C ₈₆)
87.	C ₈₇ bicyclic terpane (C ₈₆ and C ₈₇)
88.	C ₈₈ bicyclic terpane (C ₈₇ and C ₈₈)
89.	C ₈₉ bicyclic terpane (C ₈₈ and C ₈₉)
90.	C ₉₀ bicyclic terpane (C ₈₉ and C ₉₀)
91.	C ₉₁ bicyclic terpane (C ₉₀ and C ₉₁)
92.	C ₉₂ bicyclic terpane (C ₉₁ and C ₉₂)
93.	C ₉₃ bicyclic terpane (C ₉₂ and C ₉₃)
94.	C ₉₄ bicyclic terpane (C ₉₃ and C ₉₄)
95.	C ₉₅ bicyclic terpane (C ₉₄ and C ₉₅)
96.	C ₉₆ bicyclic terpane (C ₉₅ and C ₉₆)
97.	C ₉₇ bicyclic terpane (C ₉₆ and C ₉₇)
98.	C ₉₈ bicyclic terpane (C ₉₇ and C ₉₈)
99.	C ₉₉ bicyclic terpane (C ₉₈ and C ₉₉)
100.	C ₁₀₀ bicyclic terpane (C ₉₉ and C ₁₀₀)



Chemosynthetic Clams (*Calyptogena*)



Other bacteria metabolize methane to SCO₂, which can combine with Ca²⁺ from sea water to make CaCO₃. Carbonate crusts are found in many places, commonly associated with faults. Areas with carbonate crusts are likely fossil vent sites.



Control Room on the Pt. Lobos where the ROV *Ventana* is directed

Acknowledgements

We thank the captains, crews, and ROV pilots of the RV *Pt. Lobos* whose skill made this work possible.